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EFFECTS OF RUNWAY GROOVING ON AIRCRAFT TIRE SPIN-UP BEHAVIOR

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16. Abstract

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The results of this study indicate that grooving a runway generally reduces wheel spin-up time but does not appreciably affect the maximum wheel spin-up drag loads, at least for the ground speeds of these tests. Tire-tread damage in the form of chevron cutting was observed on the grooved surfaces under some test conditions and appeared to be dependent upon ground speed, tire inflation pressure, and the runway surface material.

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EFFECTS OF RUNWAY GROOVING ON AIRCRAFT TIRE SPIN-UP BEHAVIOR

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SUMMARY

An experimental study was conducted to compare the spin-up behavior of an aircraft tire during touchdown on grooved surfaces with the corresponding behavior on similar ungrooved surfaces. The study involved the impact of 49 × 17, type VII aircraft tires at several inflation pressures upon dry grooved and ungrooved concrete and asphalt surfaces at ground speeds up to approximately 110 knots.

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INTRODUCTION

It has been demonstrated that runway grooving is an effective means for improving tire traction during aircraft ground operations under adverse weather conditions. References 1 and 2, for example, cite many experiences of the increased wet friction levels provided by pavement grooving. A number of airport runways, both military and civil, have been transversely grooved in an effort to improve all-weather airplane ground performance. However, the installation of grooves in the touchdown area of a runway introduces a potential problem to the designer of landing-gear systems. Of specific interest is the effect of a grooved pavement on the wheel spin-up behavior during touchdown since this behavior, particularly the drag load, plays a major role in defining the landing-gear structure. No information exists on the treatment of this problem and the purpose of this paper is to fill that need, at least partially.

This report presents the results of a limited experimental study to compare the spin-up behavior of an aircraft tire during touchdown on dry grooved surfaces with the corresponding behavior on similar dry ungrooved surfaces. The study involved the impact of 49 × 17, type VII aircraft tires upon grooved and ungrooved concrete and asphalt surfaces at ground speeds up to approximately 110 knots. The results of these tests are compared on the basis of drag load and wheel spin-up time from data recorded during touchdown.

SYMBOLS

Values are given in both SI and U.S. Customary Units. The measurements and calculations were made in U.S. Customary Units and converted to SI units.

D_{max}	maximum wheel spin-up drag load
p	tire inflation pressure
t_o	time from touchdown to full wheel spin-up
V_H	forward ground speed at touchdown
V_V	wheel vertical velocity (sink rate) at touchdown
μ	drag-force friction coefficient
ω	instantaneous wheel angular velocity
ω_o	full spin-up wheel angular velocity

APPARATUS AND TEST PROCEDURE

The touchdown spin-up tests were performed at the Langley landing-loads track and utilized the main test carriage. A description of this facility and its operation is given in reference 3. The tests were conducted on 49 × 17, 26 ply rating, type VII aircraft tires which are currently used on many large military and commercial aircraft. Figure 1 is a photograph of the carriage with the installed test wheel assembly and figure 2 is a close-up view of the wheel and shows details of the instrumented dynamometer (of the type described in ref. 3) which supports the wheel and measures the various axle loadings. The dynamometer, in turn, is attached to a drop test fixture which, during a test, is released in free fall to simulate an aircraft touchdown on a preselected test surface. The simulation is not entirely complete since no wing lift is provided and since no strut system links the wheel to the drop test fixture. However, the purpose of these tests was to compare the wheel response on grooved surfaces with that on ungrooved surfaces.

Thus, the prime requirement was to maintain comparable test conditions on the two surfaces and the need for complete aircraft touchdown simulation was relaxed.

The vertical and drag loads applied to the test wheel were measured by the dynamometer load beams and a dc generator recorded the instantaneous wheel angular velocity. The outputs from the load cells and the generator, together with signals which described the carriage ground speed and wheel vertical velocity at touchdown, were transmitted to an oscillograph recorder onboard the carriage.

Asphalt and concrete surfaces, transversely grooved and ungrooved, were selected for testing since most airport runways use these surface materials. As illustrated in figure 3, both grooved surfaces employed a widely used grooving pattern: 0.63 cm (1/4 in.) wide, 0.63 cm (1/4 in.) deep and sawed on 2.54-cm (1-in.) centers. Dry surfaces were desired for all tests to provide the highest spin-up drag load and tire-damage potential.

The testing technique involved propelling the carriage to the preselected ground speed, releasing the drop test fixture to permit the tire to impact the desired test surface, and recording the various wheel spin-up characteristics. The fixture, which applied a vertical load of approximately 155.6 kN (35 000 lb) on the wheel, was positioned in the carriage to yield, in free fall, a nominal vertical velocity of 0.46 m/sec (1.5 fps), a sink rate typical of the aircraft which employ tires of the size tested. A total of 14 tests were conducted on concrete and asphalt to acquire spin-up data under seven different conditions on both grooved and ungrooved surfaces. The seven test conditions are listed in table I

TABLE I.- TEST CONDITIONS AND SUMMARY OF SIGNIFICANT RESULTS

Test condition	Surface		p		V_H, knots	V_V		D_{max}		t_o, sec	Chevron cutting
	Material	Treatment	N/cm^2	lb/in^2		m/sec	fps	kN	lb		
1	Concrete	Ungrooved	117	170	55.2	0.46	1.51	36	8 100	0.123	None
		Grooved			54.3	.53	1.75	29.2	6 560	.128	None
2	Concrete	Ungrooved	69	100	101.3	0.34	1.11	40	9 000	0.230	None
		Grooved			105.6	.43	1.41	47.1	10 600	.187	Slight
3	Concrete	Ungrooved	117	170	105.9	0.35	1.15	41.3	9 280	0.194	None
		Grooved			108.4	.35	1.15	39.4	8 860	.200	Severe
4	Concrete	Ungrooved	117	170	113.5	0.46	1.51	45.8	10 300	0.194	None
		Grooved			110.9	.57	1.87	47	10 560	.170	Moderate
5	Concrete	Ungrooved	145	210	109.2	0.56	1.85	51.5	11 580	0.200	None
		Grooved			101.4	.53	1.74	41.1	9 240	.144	Severe
6	Asphalt	Ungrooved	117	170	104.8	0.34	1.13	42.8	9 620	0.188	None
		Grooved			107	.48	1.58	40.7	9 150	.155	Moderate
7	Asphalt	Ungrooved	145	210	94.5	0.55	1.81	43	9 670	0.139	None
		Grooved			100.7	.44	1.43	51	11 460	.116	Slight

together with a summary of the significant results. In addition to the two surfaces, these conditions included variations in the tire inflation pressure, the test ground speed, and the wheel sink rate. The tire was tested at the rated inflation pressure of 117 N/cm^2 (170 lb/in^2) and at under- and over-inflation pressure of 69 N/cm^2 (100 lb/in^2) and 145 N/cm^2 (210 lb/in^2), respectively. One series of tests was performed at a ground speed of 55 knots and all other speeds were nominally at 105 knots, the maximum available with the carriage. Because of the variables inherent in the water jet catapult launching system, these speeds were repeatable to within approximately 5 percent.

RESULTS AND DISCUSSION

Wheel Behavior

The results of the experimental study to evaluate the relative wheel spin-up behavior during touchdown on grooved and ungrooved surfaces are derived from oscillograph time histories of recorded pertinent wheel parameters. These parameters, consisting of the vertical and drag loads measured at the axle and the wheel angular velocity, are plotted in figure 4 as a function of the time from tire touchdown for the seven test conditions listed in table I. Each test condition is presented separately to permit a comparison between wheel spin-up behavior on grooved and ungrooved surfaces. The instant of touchdown was taken from the records as that time at which the wheel first experienced a vertical loading.

To effect a true comparison between the data from the grooved and ungrooved surfaces, it is desirable that the test variables associated with each test condition and noted in the figure be held constant. As discussed earlier, the forward ground speed V_H was repeatable to within approximately 5 percent. Differences are also noted in the wheel vertical velocity V_V and the rate of vertical loading because of bearing friction in the drop-test fixture.

The data of figure 4 indicate that, in general (five of the seven test conditions), the wheel reached full spin-up in less time on the grooved surfaces than on the ungrooved; this result corroborates the flight-test data of reference 4. The figure also indicates that the drag load during spin-up is, in general, directly related to the vertical loading rate on the wheel. Despite variations in this rate, however, there is no discernible trend to support any argument relative to the influence of grooving on the maximum spin-up drag loads. The maximum spin-up drag loads on the two surfaces for test conditions 3, 4, and 6 are essentially the same whereas the remaining four conditions show inconclusive correlation. Hence, for the test conditions of this report, which include variations in the tire inflation pressure and both concrete and asphalt runway surfaces, it appears that grooving a runway does not affect the maximum wheel spin-up drag loads, at least for ground speeds up to approximately 110 knots.

The time histories of figure 4 further indicate that for a given test condition, differences in vertical load are accompanied by corresponding differences in drag load on the two surfaces during spin-up; thereby it is suggested that the friction levels on the two surfaces might be comparable. Accordingly, the drag-force friction coefficients were calculated from the instantaneous wheel loadings measured during spin-up following touchdown on grooved and ungrooved surfaces for the seven different test conditions. These coefficients are presented in figure 5 as a function of the ratio of the wheel rotational velocity ω to the velocity at full spin-up ω_o. The figure shows that the friction coefficients developed on the grooved and ungrooved surfaces are comparable except for test conditions 3, 5, and to a lesser extent, condition 7 where the friction coefficients developed on the ungrooved surfaces are considerably lower than those on the corresponding grooved surfaces. The low friction levels associated with the ungrooved concrete (test conditions 3 and 5) may possibly be attributed to a degree of water contamination on the tire and/or the surface due to overspray from the water jet catapult propulsion system. (The ungrooved concrete was the closest surface to the catapult.) Typically, however, the variation of friction coefficient with spin-up is characterized by a high friction level at the onset of rotation which decreases as the temperature in the footprint increases (effectively a locked-wheel skid condition at touchdown) and then gradually increases as the initial tire contact patch rotates out of the footprint. With further tire rotation, the friction coefficient, particularly for the ungrooved surfaces, increases to a value which roughly corresponds to the maximum braking friction coefficient for an unheated tire when the ratio ω/ω_o is approximately 0.8 and then decreases toward the free-rolling resistance value when the tire is completely spun up. The more constant friction coefficient associated with the grooved surfaces during spin-up may account for the generally shorter spin-up times noted for those surfaces.

Tire-Tread Damage

During the course of this study, it was observed that under some test conditions, the test tire experienced damage in the tread during touchdown on the grooved surfaces. This damage, shown in figure 6, was in the form of localized chevron cuts and is denoted in table I as varying in intensity from "slight" to "severe." (The term "chevron cuts" is derived from the general shape of the superficial cuts in the damaged area.) "Severe" chevron cutting is defined by cut depths up to 0.42 cm (5/32 in.) which extended over circumferential tread lengths approaching 30.5 cm (12 in.); "moderate" cutting is defined as damage which consisted of somewhat shallower cuts over shorter tread lengths; and "slight" chevron cutting is defined as barely discernible damage. The intensity of the damage is shown to become generally more severe with increasing ground speed and/or inflation pressure. It is interesting to note that the tire of test conditions 4 and 7 was that of a different manufacturer than those employed in the other conditions. It is conceivable that the rubber composition of this tire may differ from the others and account for the reduced susceptibility to chevron cutting, as observed between conditions 3 and 4.

A comparison of the chevron cutting results obtained on the two surface materials (test conditions 3 and 6, for example) further suggests that grooved asphalt is less damaging to the tires than grooved concrete. This difference may be attributed to the edges of the sawed asphalt grooves which, as seen in figure 3, are less sharp and distinct than those resulting from the sawed grooving operation on concrete.

CONCLUSIONS

An experimental study was made to compare the spin-up behavior of a 49×17, type VII aircraft tire during touchdown on dry grooved surfaces with the corresponding behavior on similar dry ungrooved surfaces. The results of this study for test conditions which included variations in the tire inflation pressure and both concrete and asphalt runway surfaces, suggest the following conclusions:

1. Grooving a runway does not appreciably affect the maximum wheel spin-up drag loads, at least for ground speeds up to approximately 110 knots.

2. Grooving a runway surface generally reduces wheel spin-up time.

3. Tire-tread damage (chevron cutting) was experienced on the grooved surfaces under some test conditions. The extent of chevron cutting appeared to become more severe with increasing ground speed and/or increasing tire inflation pressure. Grooved concrete surfaces appear to be more damaging to the tires than grooved asphalt surfaces.

It should be emphasized that these results are for ground speeds up to approximately 110 knots, the maximum available with the test apparatus, whereas, in practice, aircraft which employ this tire size generally touch down at speeds approaching 150 knots.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., July 14, 1971.

REFERENCES

1. Anon.: Pavement Grooving and Traction Studies. NASA SP-5073, 1969.
2. Yager, Thomas J.; Phillips, W. Pelham; Horne, Walter B.; and Sparks, Howard C. (With appendix D by R. W. Sugg): A Comparison of Aircraft and Ground Vehicle Stopping Performance on Dry, Wet, Flooded, Slush-, Snow-, and Ice-Covered Runways. NASA TN D-6098, 1970.
3. Joyner, Upshur T.; Horne, Walter B.; and Leland, Trafford J. W.: Investigations on the Ground Performance of Aircraft Relating to Wet Runway Braking and Slush Drag. AGARD Rep. 429, Jan. 1963.
4. Grisel, Charles R.: Investigation of the Effects of Runway Grooves on Wheel Spin-Up and Tire Degradation. FAA-RD-71-2, Apr. 1971.

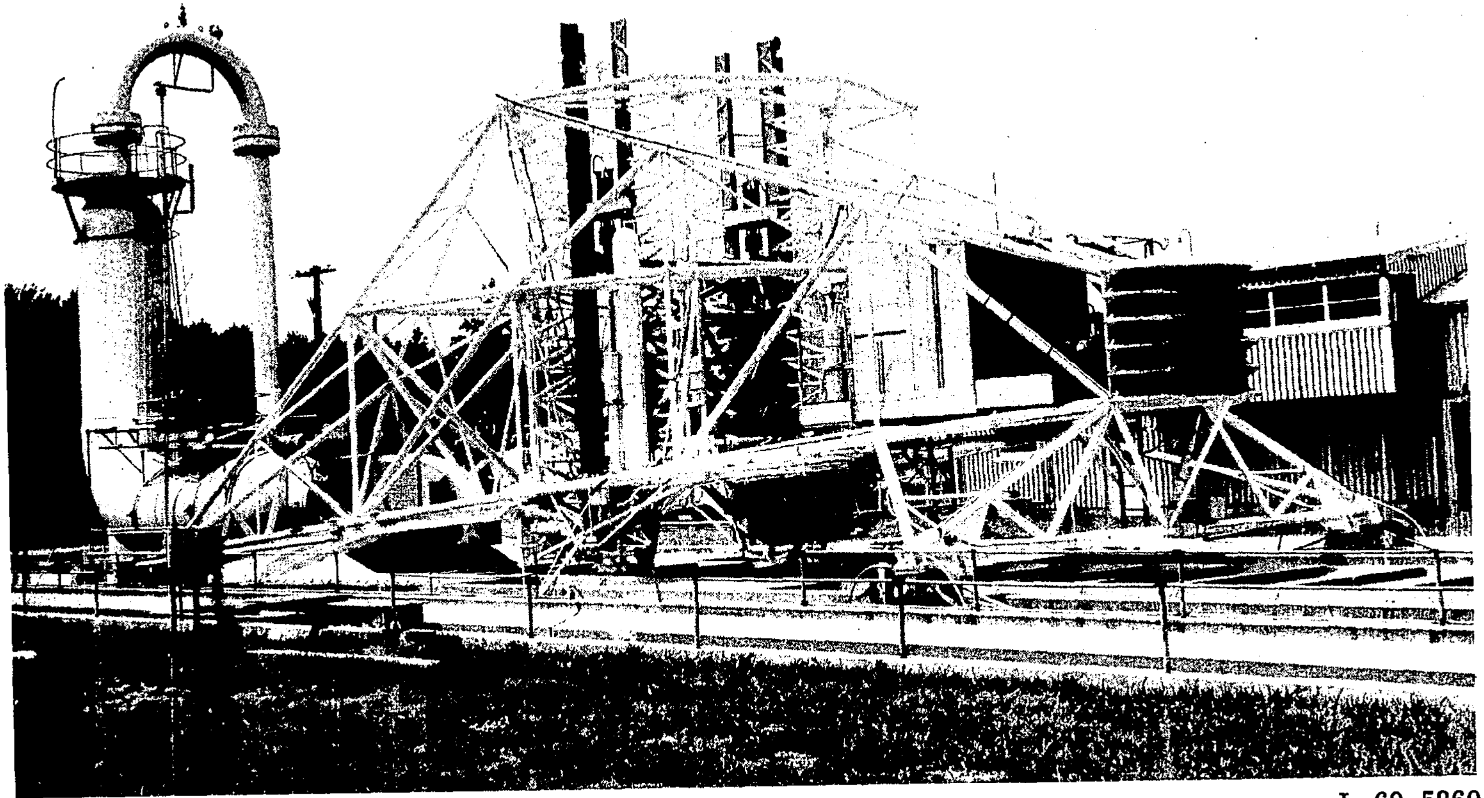

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Figure 1.- Photograph of test carriage at Langley landing-loads track prior to launch.

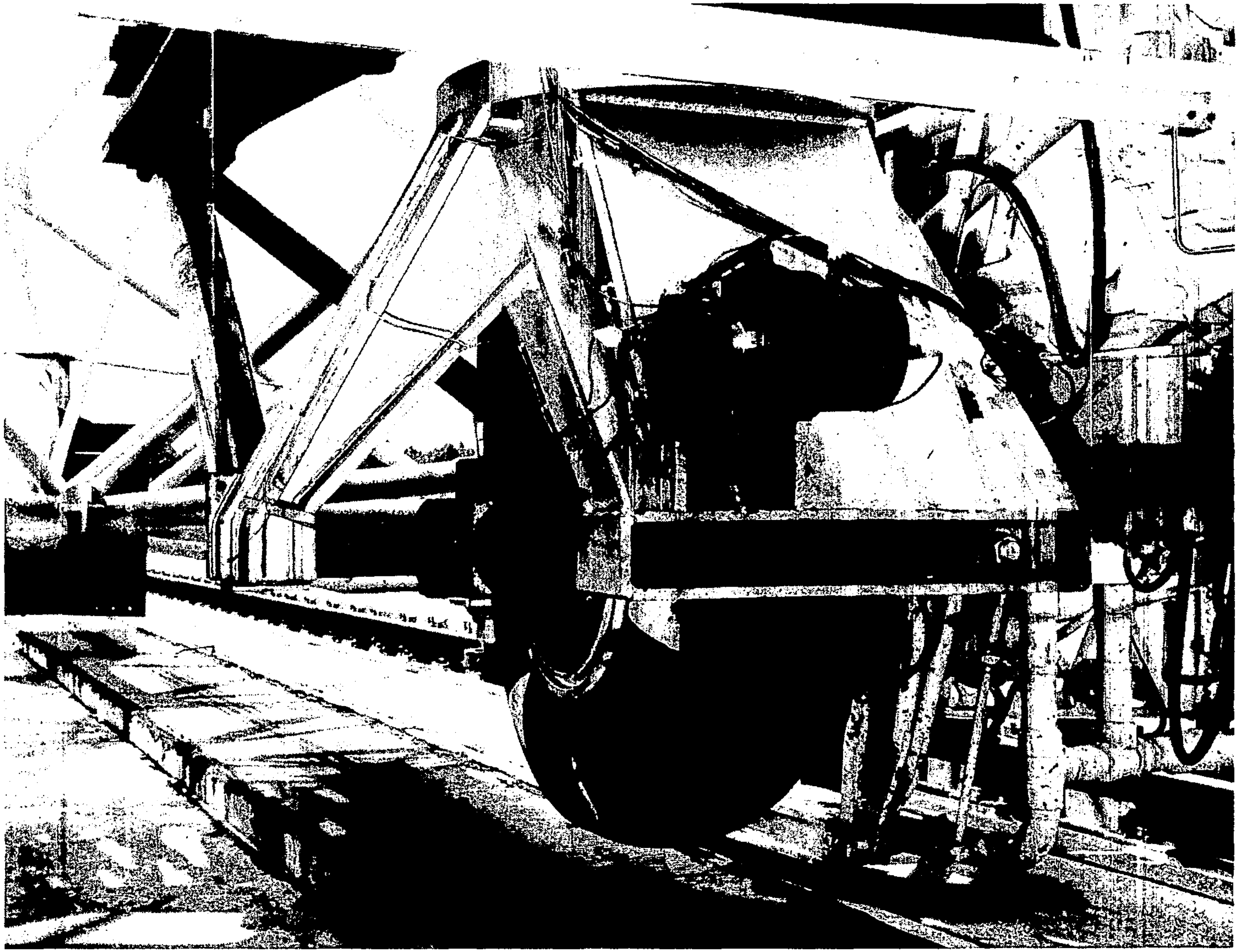

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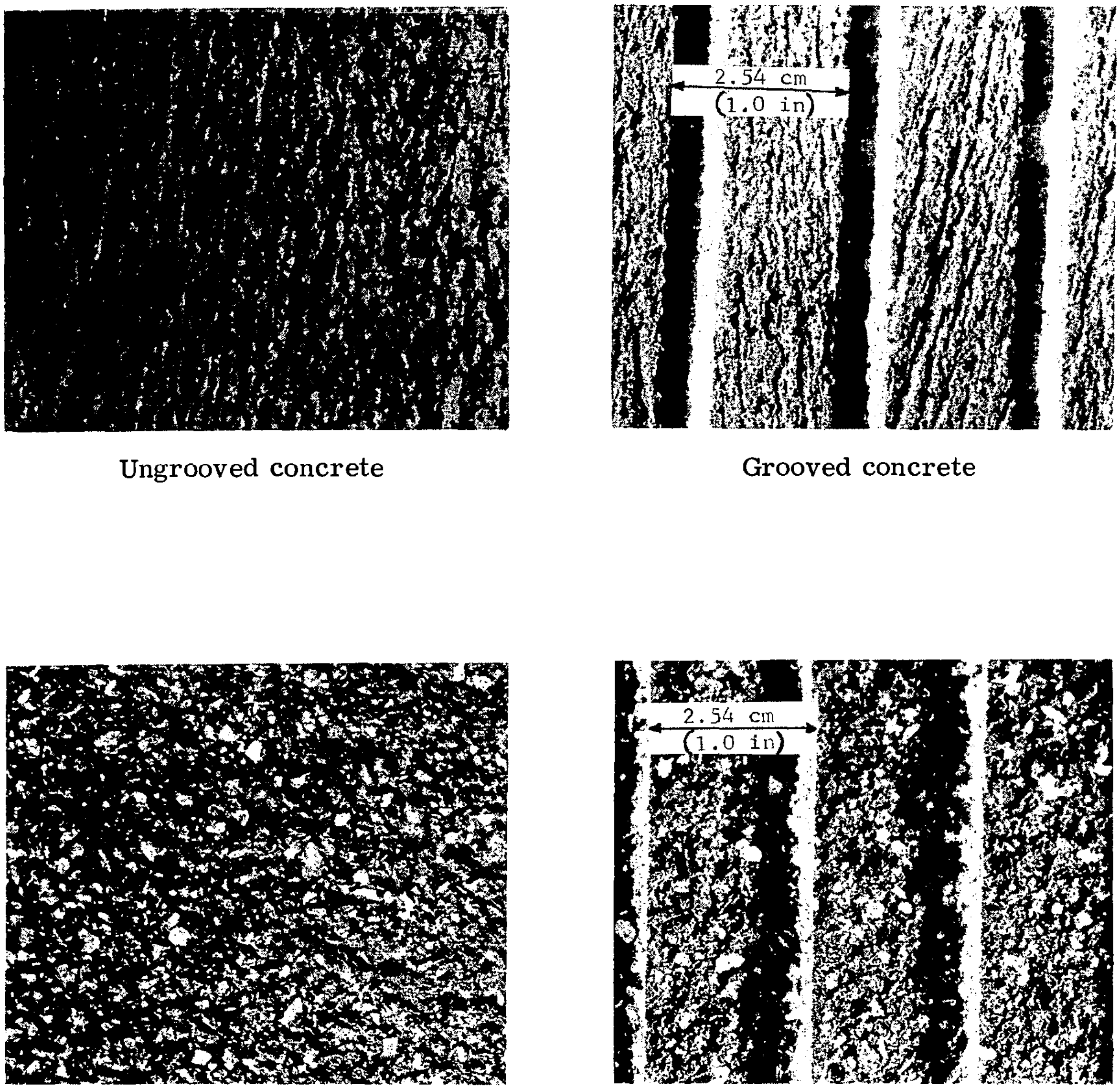
Figure 2.- Closeup of test tire showing load dynamometer.



Ungrooved concrete

Grooved concrete

Ungrooved asphalt

Grooved asphalt

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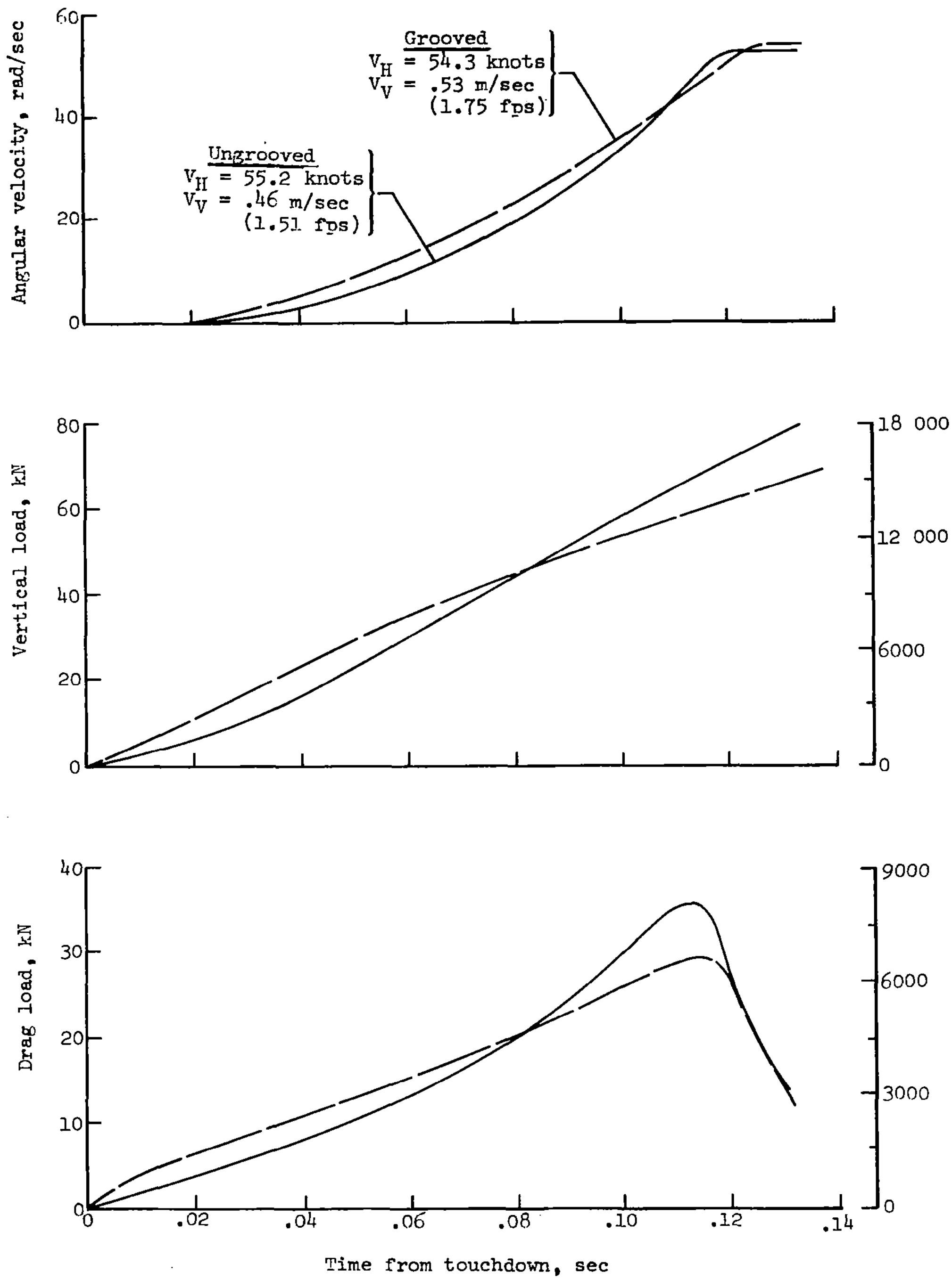
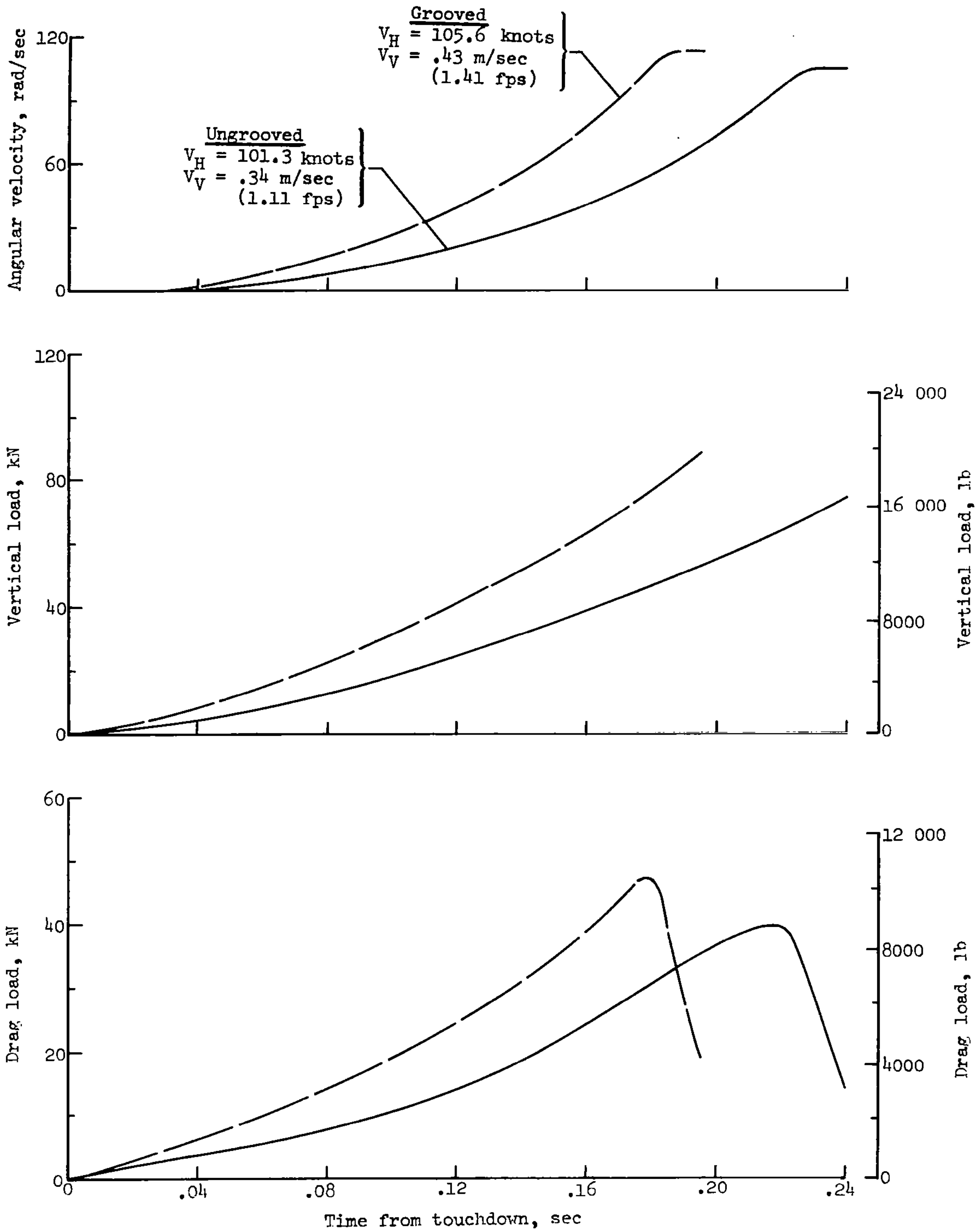
Figure 3.- Photographs of the test surfaces.



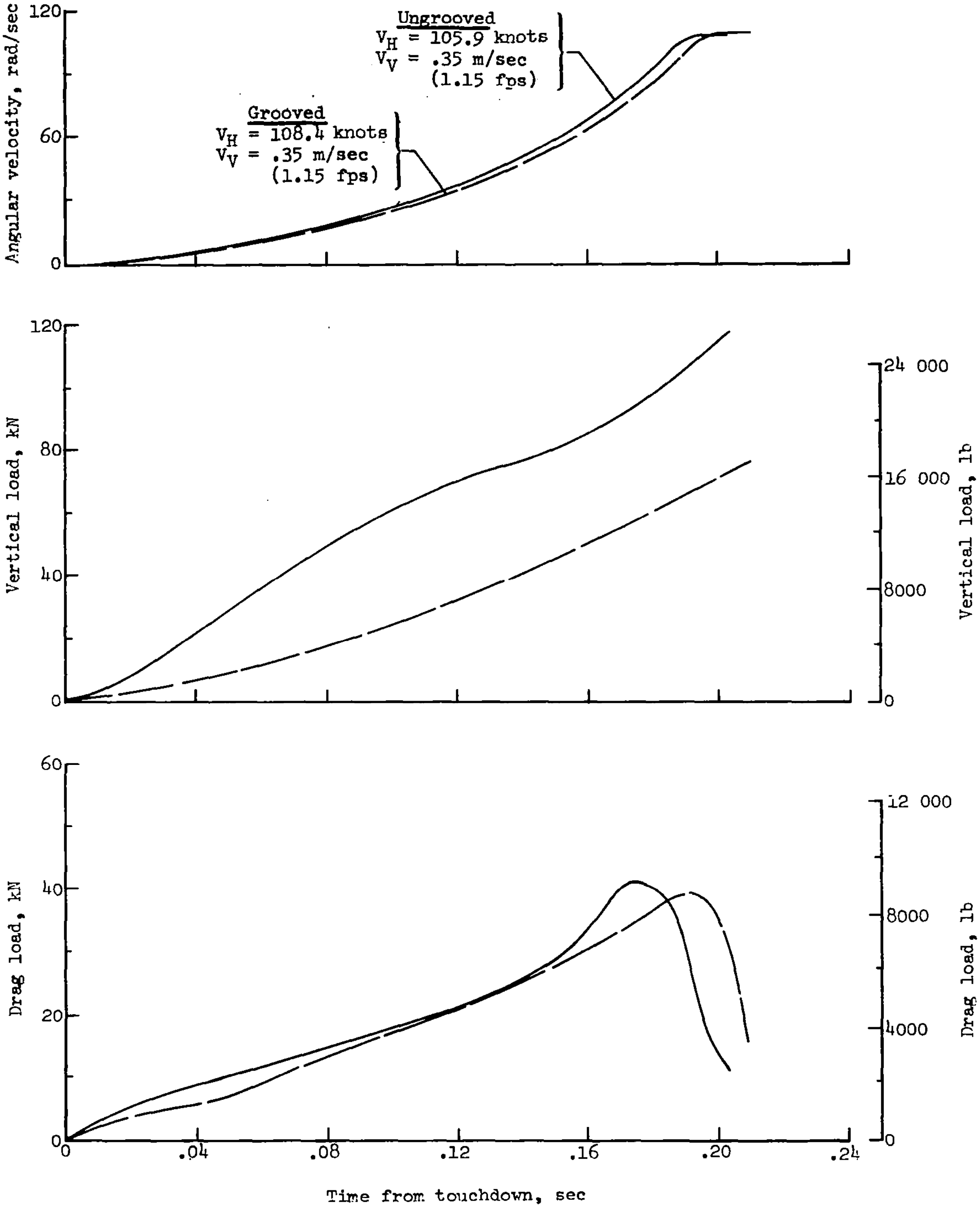
(a) Test condition 1. Concrete surface; p = 117 N/cm^2 (170 lb/in^2).

Figure 4.- Variation of wheel parameters during spin-up following touchdown on grooved and ungrooved surfaces.



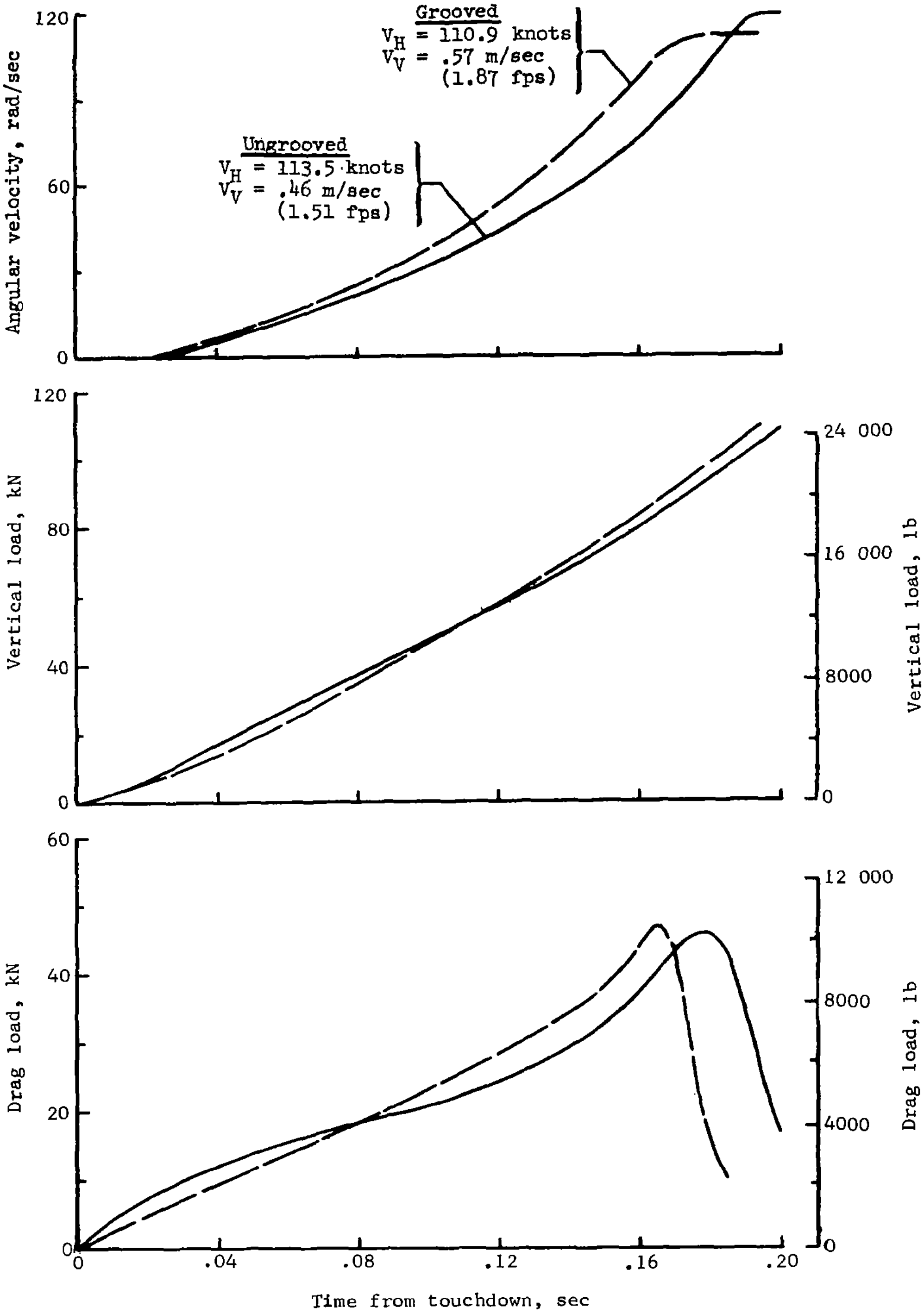
(b) Test condition 2. Concrete surface; $p = 69\ N/cm^2$ ($100\ lb/in^2$).

Figure 4.- Continued.



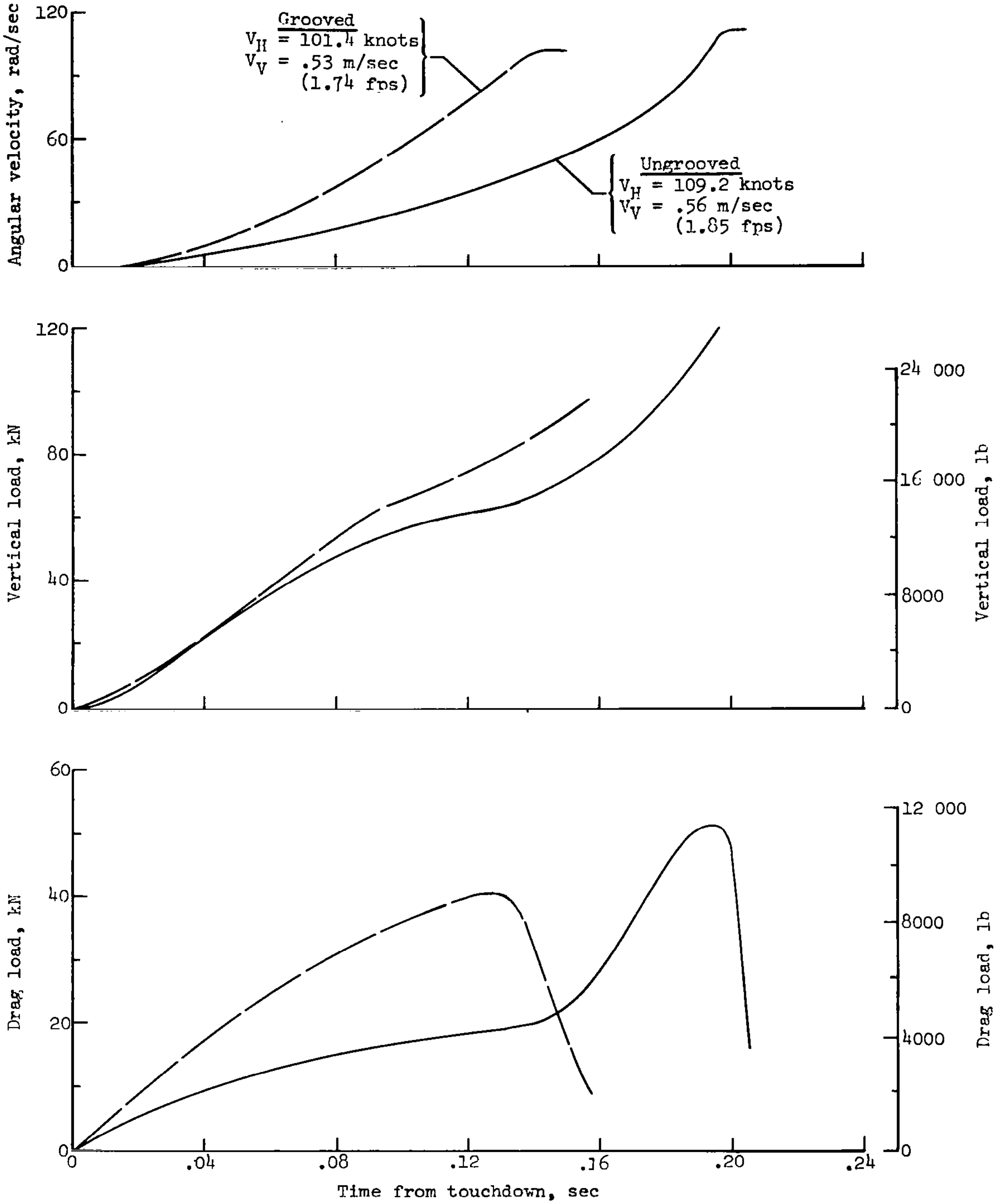
(c) Test condition 3. Concrete surface; p = 117 N/cm^2 (170 lb/in^2).

Figure 4.- Continued.



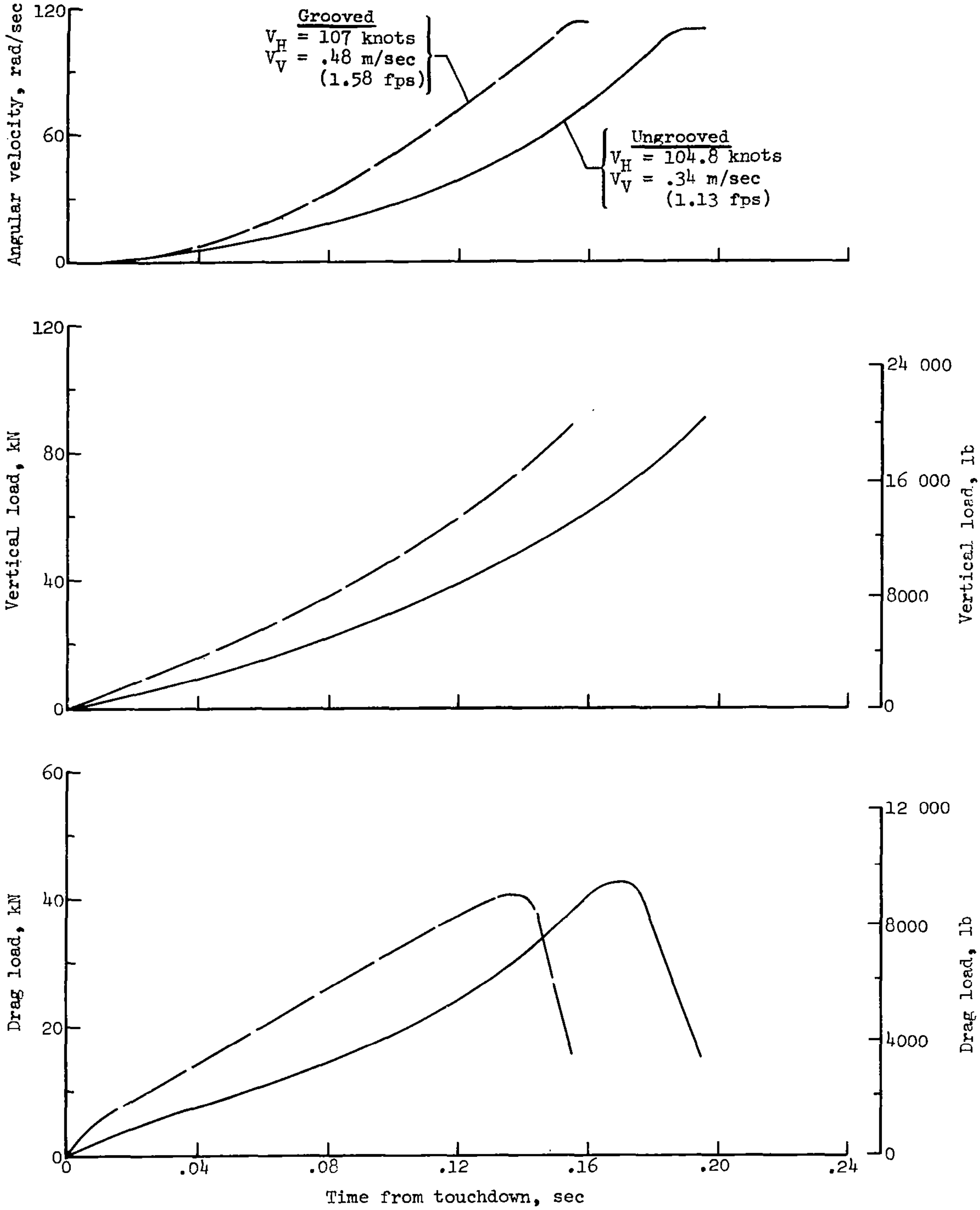
(d) Test condition 4. Concrete surface; p = 117 N/cm^2 (170 lb/in^2).

Figure 4.- Continued.



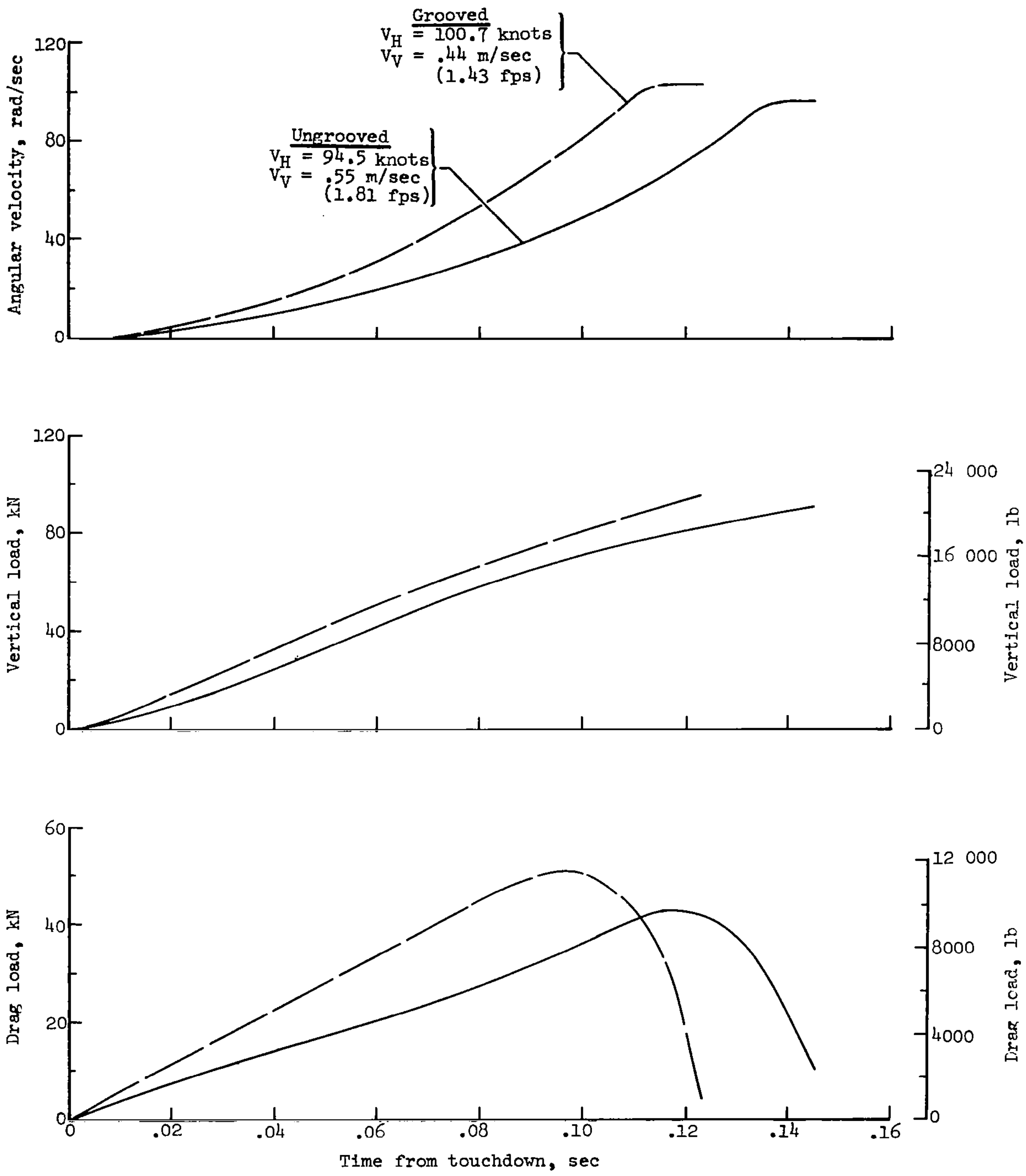
(e) Test condition 5. Concrete surface; p = 145 N/cm^2 (210 lb/in^2).

Figure 4.- Continued.



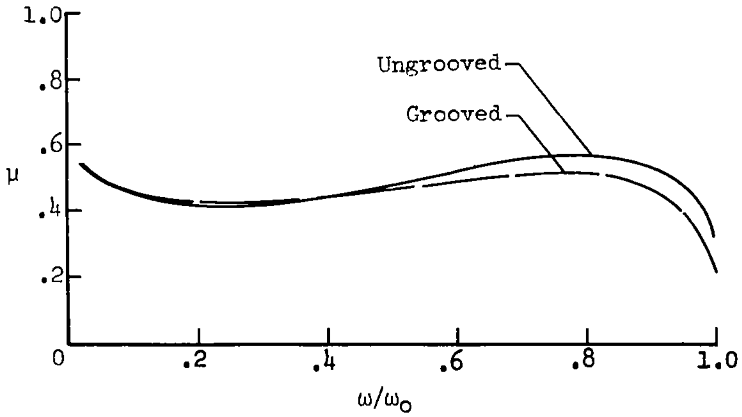
(f) Test condition 6. Asphalt surface; p = 117 N/cm2 (170 lb/in2).

Figure 4.- Continued.

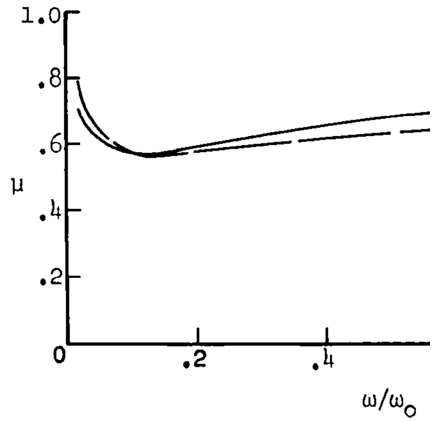


(g) Test condition 7. Asphalt surface; $p = 145\ N/cm^2$ ($210\ lb/in^2$).

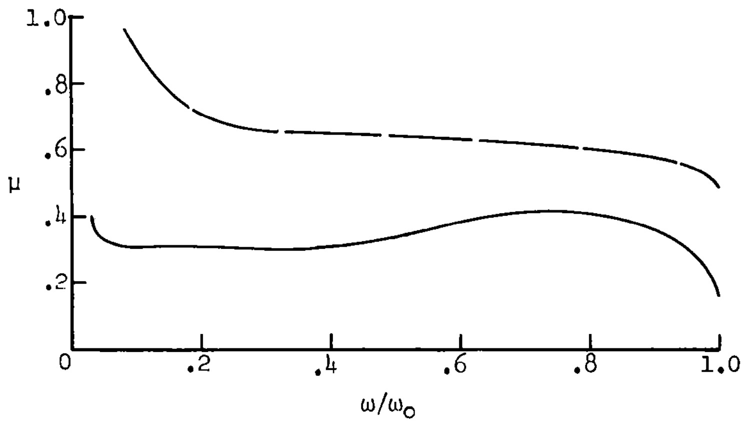
Figure 4.- Concluded.



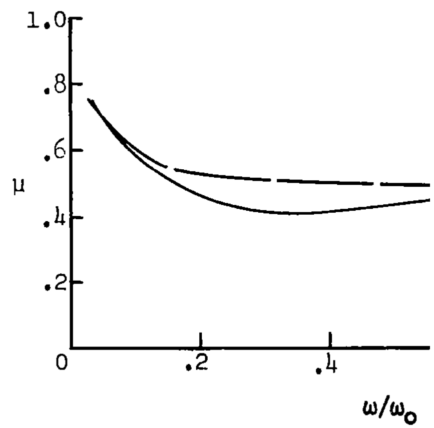
(a) Test condition 1.



(b) Test conditi

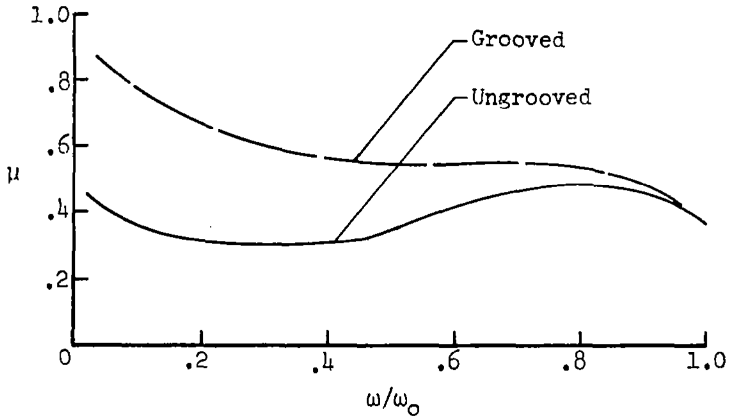


(c) Test condition 3.

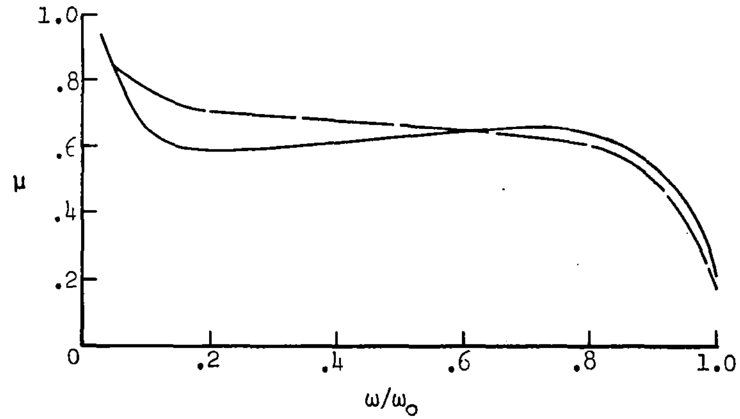


(d) Test conditi

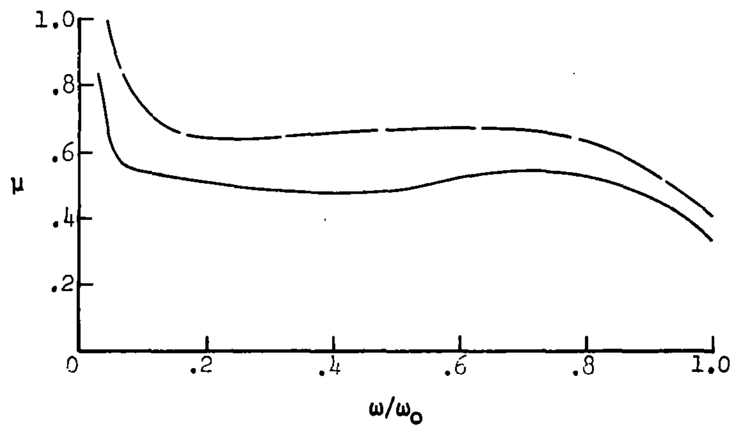
Figure 5.- Variation of drag-force friction coefficient during wheel spin-up followi
on grooved and ungrooved surfaces.



(e) Test condition 5.



(f) Test condition 6.



(g) Test condition 7.

Figure 5.- Concluded.

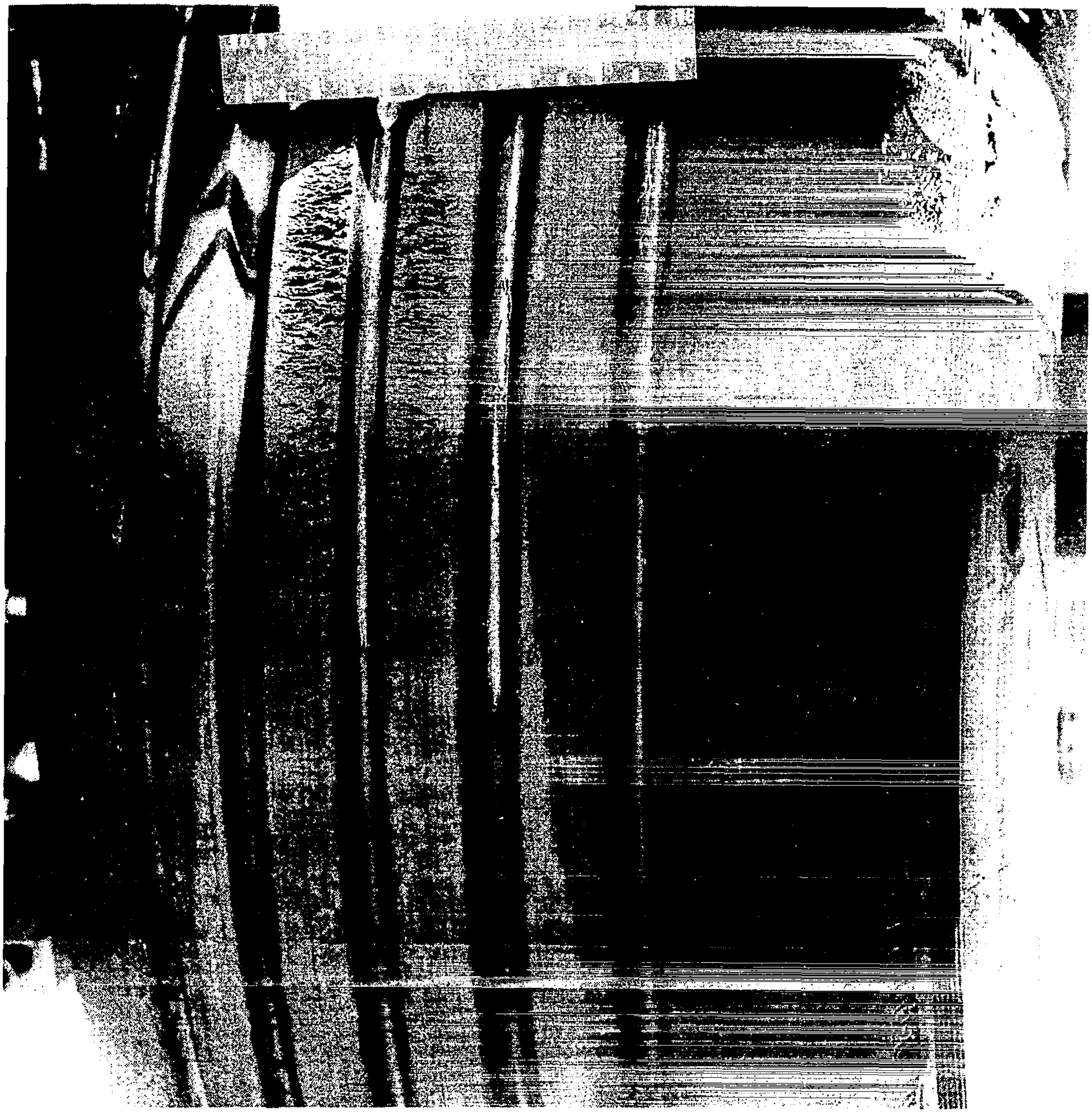


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Figure 6.- Photograph of tire following touchdown on grooved concrete showing "severe" chevron cutting. Test condition 3.

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